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(71) Applicant: HUNTINGTON ALLOYS, INC.
Huntington West Virginia 25720(US)

(72) Inventor: Eiselstein, Herbert Louis
6 Elwood Avenue
Huntington West Virginia 25705(US)

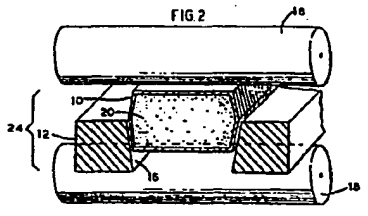
(72) Inventor: Lingenfelter, Allen Cloy
Blue Sulphur Gardens
Ona West Virginia 25545(US)

(74) Representative: Lockwood, Barbara Ann et al,
Thames House (Fifth Floor) Millbank
London SW1P 4QF(GB)

(54) **A process for the consolidation of metal powder.**

(57) A process for consolidating metal powders into slab configurations is disclosed in which the metal powder is encapsulated, heated and inserted in a containment die (12) and is subjected to a rolling operation to consolidate the powder.

FIG 2



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Abstract

A process for consolidating metal powders into slab configurations is disclosed in which the metal powder is encapsulated, heated and inserted in a containment die (12) and is subjected to a rolling operation to consolidate the powder.

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A process for the consolidation of metal powder

The present invention r lates to a process for the consolidation of metal powders, which powders may be elemental or prealloyed, to give a product having a slab configuration, i.e. intermediate between ingot and plate.

The advantages of producing wrought products from metal powders are well documented. The products are frequently unique, or superior to conventional products, and are often cheaper to produce. Particularly advantageous results are obtained from the application of powder metallurgy techniques to superalloys, where much greater homogeneity and formability is achieved. Metal powders can be consolidated by a number of processes. Most commonly for prealloyed powders the powder is hot isostatically pressed (HIP) to give a billet, which is then generally forged prior to further processing. Whilst very effective the HIP process is expensive to install, and to operate and maintain. Moreover the size of the billet to be produced is limited by the size of the hot isostatic press available.

An alternative process which has been used comprises vacuum hot pressing in which the powder is consolidated in a cylindrical die under vacuum at high temperatures. Pressure is usually applied to the powder through one, or two, movable rams. The process is very long and expensive, and once again the size of the billet is limited by the size of the press available. Extrusion of powders has been extensively used for the production of rod and bar. The powders are sealed under vacuum, loose sintered and then hot extruded. Canned powders have also been sintered and subsequently rolled to give flat sheet.

The present invention is based on the discovery that powders can be consolidated into slab configurations by a simple, economic process using

existing rolling mill equipment.

According to the present invention there is provided a process for the consolidation of metal powder comprising encapsulating the metal powder in a container and heating the encapsulated powder to a rolling temperature, and rolling in a rolling mill to effect consolidation, characterised in that the encapsulated powder is inserted in a containment die having a cavity of the desired slab configuration and is then rolled in the rolling mill whereby the powder is consolidated by forcing the container into the die to form a consolidated powder product having a slab configuration, and removing the consolidated product from the die.

The consolidated product may be removed from the container prior to further working.

The container may be constructed from any canning material conventionally used in powder metallurgy, for example mild steel. The material must of course withstand high temperatures and pressures. The containment die must be strong enough to resist bulging and breakage when the assembly is subjected to rolling. Preferably a thick box frame having a central cavity is used. It is preferred that the cavity has a taper, for example of about fifteen degrees in order to allow easy stripping of the container from the die. It has been found that such a taper also increases the movement of powder in the container. The die material must also be able to withstand elevated temperatures, since it is used in conjunction with a heated container. It may also be desirable to preheat the die in order to prevent the chilling of the encapsulated powder prior to rolling. One material which has been found to be suitable for the containment die is INCONEL alloy 718. (INCONEL is a registered Trade Mark.). This has been used successfully after preheating to about 540°C

without any significant loss of strength.

In the process of the invention c mpaction densities of in excess of 90% are necessary in order to permit subsequent rolling without the aid of an additional die. The encapsulated powder is generally initially at a density of about 62 to 64% theoretical density. It is preferred that a reduction of from 8:1 to 10:1 is used to achieve full density and to optimise physical properties and structure of mechanically alloyed alloys treated by the process. Thus, to produce a slab of approximately 5 cm thickness by the process of the invention a container of about 50 cm thickness containing the metal powder to be compacted would be necessary.

An example will now be described by reference to the accompanying drawings in which

Figure 1 shows in perspective apparatus for use in a process of the present invention,

Figure 2 is a perspective view partially cut away illustrating a step of the process of the present invention, and

Figure 3 is a cross-sectional elevation of a compacted product produced by the processof the invention.

Metal powder 20 was introduced into a container, shown as 10 in Figure 1 of the drawings. The container was evacuated and sealed by welding. (It is possible to purge the powder with an inert, or non-reactive gas, but it is preferable to evacuate the container prior to sealing). The container 10 shown consists of a rectangular box, the side walls inclining outwards from the base to the midpoint height and inwards from the midpoint height to the top. Although many can shapes may be used in the process of the invention, it is believed that the shape of can shown in Figure 1 gives

optimum results with a minimum of dg cracking and incomplet edge densification which can arise with alternative configurations.

The encapsulated powder was then charged into a furnace and heated to a rolling temperature dependant on the metal powder. In one example INCOLOY alloy MA 754 (INCOLOY is a registered Trade Mark) powder was used and the container was heated to 1149°C, about 250°C below the solidus of the powder. The heated container was then inserted in a thick box frame die 12 having a central cavity 14. The cavity has a taper 16 of about fifteen degrees. The die 12 was made from INCONEL alloy 718, and had been preheated to about 540°C to avoid chilling the powder.

The container was inserted into the heated die 12 so that initially about half the container extended outside the die. Obviously if too much of container 10 is exposed it will be smashed in the rolling mill during the subsequent rolling step. Conversely if the container 10 sits too deeply in the die 12 there will be insufficient compaction effected by rolling. The assembly of container and die was then rolled in a conventional rolling mill between rollers 18 as shown in Figure 2, whereby the encapsulated powder 20 flows into the die cavity 14 but elongation is prevented by the die. In the present example the volume of the can was reduced by about 33% during rolling leading to compaction of the metal powder to more than 90% of theoretical density. It has been found desirable to set the rolling pressure in the rolling mill so that it is approximately that of the yield strength of the powder 20 at the rolling temperature.

After rolling, the compacted powder 22 is

stripped from the die 12 and may be decanned by mechanical or chemical treatment before further processing for example by hot rolling and/or heat treatment. However if desired such further treatments can be given to the compacted powder whilst still canned. In the case of INCOLOY alloy MA 754, the compacted powder was hot rolled from 2.54 cm after compaction to 0.76 cm or 1.27 cm after reheating to about 1150°C to give a sound crack free alloy. Some exterior defects may be observed on the product but these may be removed physically. Subsequent heat treatment at about 1316°C for half hour develops the elongated grain structure characteristic of mechanically-alloyed products.

Claims

1. A process for the consolidation of metal powder comprising encapsulating the metal powder 20, in a container 10 and heating the encapsulated powder to a rolling temperature and rolling in a rolling mill to effect consolidation characterised in that the encapsulated powder is inserted in a containment die 12 having a cavity 14 of a desired slab configuration and is then rolled in the rolling mill whereby the powder is consolidated by forcing the container into the die to form a consolidated powder product having a slab configuration and removing the consolidated product from the die 12.

2. A process as claimed in claim 1 in which the consolidated product is subsequently heat treated and/or hot rolled before or after removal from the container 10.

3. A process as claimed in claim 1 or claim 2 in which the rolling temperature is below the solidus temperature of the powder.

4. A process as claimed in any preceding claim in which the containment die is heated before the encapsulated powder is inserted therein.

5. A process as claimed in any preceding claim in which the containment die is a box frame 12.

6. A process as claimed in any preceding claim in which the cavity 14 in the containment die 12 has tapered side walls.

7. A process as claimed in any preceding claim in which the container 10 consists of a rectangular box the side walls of which incline outwards from the base to the midpoint height and inwards from the midpoint height to the top.

8. A process as claimed in any preceding claim in which about half of the container 10 extends outside the containment die 12 prior to rolling.

9. A process as claimed in any pr ceding claim when used to compact mechanically alloyed powders.

10. A slab of consolidated metal powder when produced by a process as claimed in any one of claims 1 to 9.

FIG. 1

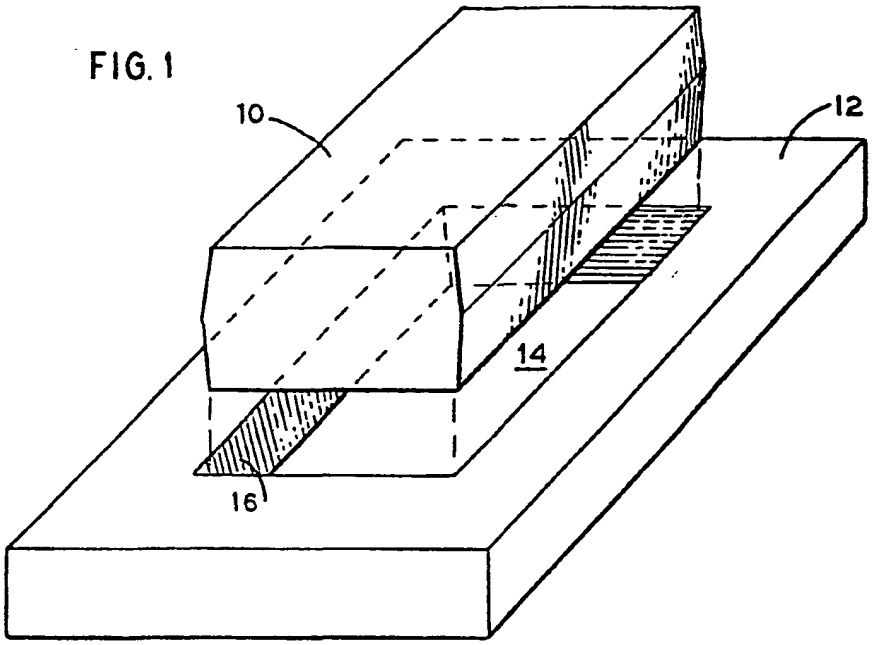


FIG. 2

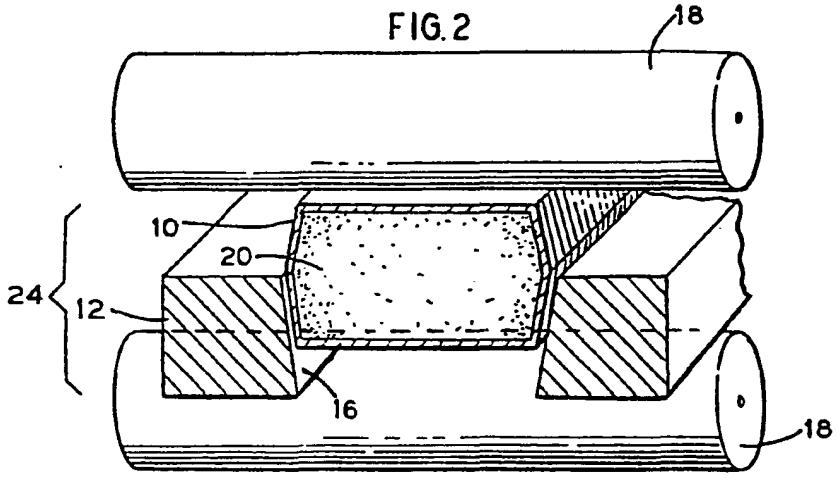
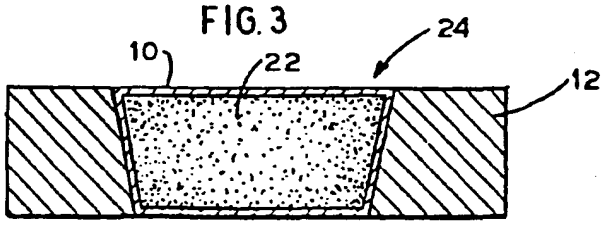


FIG. 3



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EUROPEAN SEARCH REPORT

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
X	US-A-4 126 451 (H.S. NAYAR) * Claim 17 *	1-5,8-10	B 22 F 3/18
A	DE-A-2 625 144 (DAVY-LOEWY) * Claims 1,13 *		
A	US-A-4 025 313 (H.J. SLAATS)		
A	DE-A-1 155 460 (STORA KOPPARBERGS BERGSLAGS AB)		

TECHNICAL FIELDS SEARCHED (Int. Cl. ³)

B 22 F
B 28 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	07-08-1984	SCHRUERS H.J.

CATEGORY OF CITED DOCUMENTS

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